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Bio-efficacy of botanical pesticides against mealy cabbage aphid (*Brevicoryne brassicae* L.) and bio-safety against its natural enemies in cruciferous vegetable ecosystem of Kashmir

Akhtar Ali Khan

Abstract
The two concentration of Neem oil (2% and 3%), castor oil (2% and 3%), Artemisia leaf extract (2% and 3%), Neem seed kernel extract (NSKE) @ 5% and6% and Azadirachtin (0.2% and 0.3%) compared with the treated check Dimethoate (Roger) @ 1% concentration with untreated check for their bio-efficacy against mealy cabbage aphid (*Brevicoryne brassicae* L.) and bio-safety against natural enemies were evaluated. The highest mean reduction of cabbage aphid (66.55%) was recorded against Azadirachtin @ 0.3%followed by 63.01% against same botanical pesticides@ 0.2% concentration while as lowest reduction was recorded 47.10% against Artemisia leaf extract (2%). The mean mortality of natural enemies (35.26%) against Artemisia leaf extract @ 3% followed by Azadirachtin @ 0.3% and was recorded as 32.11%. The least mortality of natural enemies was recorded as 22.92% against Artemisia leaf extract @ 3% as compared to treated check which was recorded as 70.00%. among all, Azadirachtin @ 0.3% exhibited best performance on the basis of reduction of cabbage aphid (66.55%) and also safer for natural enemies among the tested botanicals; hence, can be considered a potential botanical pesticide against cabbage aphid in Kashmir.

Keywords: bio-efficacy, bio-safety, botanical pesticides, mealy cabbage aphid, natural enemies, vegetable ecosystem

Introduction
Mealy cabbage aphid, *Brevicoryne brassicae* L. (Hemiptera: Aphididae) is an important pest of cruciferous vegetable crops in Kashmir [1, 2]. Cabbage aphids feed on the underside of the leaves and on the centre of the cabbage head [3]. They prefer feeding on young leaves and flowers and go deep into the heads [4]. Colonies of the cabbage aphid can be seen on upper and lower leaf surfaces, in leaf folds, along the leafstalk, near leaf axils [5]. The short cornicles with waxy coating found on cabbage aphids help differentiate cabbage aphids from other aphids that may attack the same host plant [6, 7]. Aphids feed by sucking sap causes yellowing, wilting and stunting of plants. Severely infested plants become covered with a mass of small sticky aphids (due to honeydew secretions), which can eventually lead to leaf death and decay [8]. Cabbage aphids are important vectors of plant diseases including beet western yellows virus (BWYV, syn. turnip yellows virus), cauliflower mosaic virus (CaMV) and turnip mosaic virus (TuMV) all of which cause damage in canola [9, 10]. Yield loss is greater in crops that have been infected as seedlings. Viral infection can occur past the rosette stage of canola growth but these often have little effect on yield [11].
There are many effective natural enemies of aphids such as Hoverfly larvae [12-14], lacewings [15-17], ladybird beetles [18-20], and spiders [21, 22] are known predators that can suppress populations [23, 24]. Aphid parasitic wasps lay eggs inside bodies of aphids and evidence of parasitism is seen as bronze-coloured enlarged aphid mummies [25].
Repeated use of broad-spectrum insecticides against pests have caused secondary outbreaks, insect resistance to insecticides [26], and deleterious effects to beneficial non-target insects [27, 28]. Selective insecticides have modes of action that target a specific pest but can minimize harmful effects to natural enemies [29, 30]. Bacci *et al*. [31], predict that insecticides are likely to remain as one of the tools for the management of cabbage aphid but advocate for integrated pest management that also utilizes biological control [32]. Use of practices that protect or minimize harm to beneficial organisms are forms of "conservation" biological control [2].

Though other commercialized insecticides are available, this study focuses on insecticides that are permitted for use in organic systems and will be referred to as "organic-insecticides or botanical pesticides and most are botanical insecticides that are naturally derived from plants [33]. Our objective of the study was to evaluate the botanical pesticides for the management of cabbage aphids and also study the biosafety of these botanicals for natural enemies that's help to use these botanical pesticides as tools of integrated pest management programme of cruciferous vegetable ecosystem.

Materials and Methods

Field experiments were laid out at Srinagar to evaluate the botanical pesticide against cabbage aphid and their natural enemies in cruciferous ecosystem. Two concentration of Neem oil (2% and 3%), castor oil (2% and 3%), Artemisia leaf extract (2% and 3%), Neem seed kernel extract (NSKE) @ 5% and6% and Azadirachtin (0.2% and 0.3%) compared with the treated check Dimethoate (Roger) @ 1% concentration with untreated check for their bio-efficacy against cabbage aphid and bio-safety against natural enemies. Each concentration was replicated five times. Pre-treatment count was taken one day before treatment and post treatment count was taken after 1,7 and 15 days after treatment by taking a random sample of per leaf of cabbage crop. Similarly, the observation of natural enemies was also recorded one day before treatment and 1, 7 and 15 days after treatment by taking a random sample of 10 leaves.

The trails were laid out in randomized block design cabbage crop plants. Percent reduction (mortality was workout by computing the differences between pre- and post-treatment population of cabbage aphid and their natural enemies by applying Abbot's formula. The data was subjected to analysis of variance and critical differences at 5% level of significance was work out.

Results and Discussion

Bio-efficacy of botanical pesticides on mealy cabbage aphid and bio-safety of on their natural enemies were studied at Srinagar are presented in Table 1 and 2.

Bio-efficacy of botanical pesticides against mealy cabbage aphid

The maximum mean population reduction of cabbage aphid (55.09%) recorded against Azadirachtin (0.3%) and least (37.94%) against Artemisia leaf extract (2%) at 1st days after treatment (Table 1). Other treatments viz., Neem oil @ 2% and 3% showed 49.74% and 51.24% reduction; Castor oil @ 2% and 3% showed 42.10% and 44.54%; Artemisia leaf extract @ 3% gave 38.21%; NSKE @ 4% and 5% showed 48.01% and 49.76% and Azadirachtin @ 0.2% exhibited 53.26% reduction as compared to treated check Dimethoate 30EC @ 1.0ml/liter of water. First days after treatment, alate cabbage aphid reduction was maximum (52.74%) in case of Azadirachtin (0.3%) followed by same botanical pesticide @ 0.2% concentration (50.00%) which was statistically similar to Neem oil @ 3% concentration at first days after treatment Least reduction of alate cabbage aphid (34.37%) was recorded against castor oil (2%) as compared to treated check of Dimethoate 30EC@ 1.0ml/liter of water was 64.40% reduction at first days after treatment. In case of apterous aphid, the maximum reduction (68.81%) was also recorded against Azadirachtin (0.3%) concentration and least (38.09%) also recorded against castor oil @ 2% concentration first day after treatment as compared with the reduction of cabbage aphid (70.83%) under treated check.

Similar results was also recorded at 7th days after treatments with increasing trends, the maximum reduction of nymph, alate and apterous aphid were 63.42%, 59.80% and 75.26% in case of Azadirachtin @ 0.3% concentration, respectively and lowest nymph and alate reduction (48.20% and 43.68%) in case of Artemisia leaf extract @ 2% and in case of apterous aphid lowest reduction (48.80%) was recorded against castor oil (2%). In case of treated check (Dimethoate 30EC @ 1.0ml/liter of water) the reduction of cabbage aphid was also increase (75.0% of nymph, 7.78% of alate and 78.12% of apterous) at 7th days after of treatment.

At 15th day after treatment the reduction of nymph, alate and apterous cabbage aphid also increased and was highest (74.51%, 69.60% and 79.56%) in case of Azadirachtin@ 0.3% concentration and lowest, 53.07%, 48.95% and 60.46% in case of Artemisia leaf extract (2%), castor oil (2%) and neem oil (2%), respectively.

The cumulative mean reduction of cabbage aphid nymph, alate and apterous were recorded highest, 64.34%, 60.78% and 74.54% in case of Azadirachtin @ 0.3% while as lowest, 46.40%, 43.36% and 49.59%, respectively in case of Artemisia leaf extract (2%) against nymph and alate and against apterous aphid in case of castor oil (2%). In case of treated check (Dimethoate 30EC @ 1.0ml/liter of water) the reduction 80.66%, 82.02% and 77.08% of nymph, alate and apterous aphids were recorded (Table 28).

The total highest mean reduction of cabbage aphid (66.55%)was recorded against Azadirachtin @ 0.3%followed by 63.01% against same botanical pesticides@ 0.2% concentration while as last reduction was recorded 47.10% against Artemisia leaf extract (2%). In treated check, the reduction was recorded 79.92% as compared to other treatments viz., neem oil@2% (53.36%), Neem oil@3% (57.40%), castor oil@ 2% (47.85%), castor oil@ 3% (51.89%), Artemisia leaf extract@ 3% (51.32%), NSKE @ 4% (52.48%), NSKE @ 5% (55.50%) and Azadirachtin @ 0.2% (63.01%) (Table 1). Least information is available for comparing the impact of botanical pesticides against meal cabbage aphid as well as their natural enemies. The toxicity of pesticides on *Aphis pomi* was studied by Khan [34] and Nahusenay and Abate [35] worked on cabbage aphid and result was quite similar to present findings.

Bio-safety of botanical pesticides against Natural enemies of meal cabbage aphid

The bio-safety of natural enemies were studied and persecuted in Table 29. First day after spray, the mortality of Coccinellids was recorded highest (22.7%) against Neem oil (3%) which was statistically similar to Castor oil @3% (22.00%) and Azadirachtin @ 0.3% (20.00%) as compared to the treated check (Dimethoate @1.0ml per liter of water) and was 55.5%. The least mortality (9.0%) of coccinellids was recorded in case of Artemisia leaf extract @ 2% followed by NSKE @2% which was recorded 10.0% at first days after treatment. At 7th day after treatment, the mortality of coccinellids was recorded highest (33.3%) against castor oil 3% followed by 31.8% against Neem oil @3% as compared with treated check (Dimethoate 30EC @ 1.0ml per liter of water) which was recorded 66.6% while as least mortality (16.6%) against Neem oil @ 2% followed by 18.0% in case of Artemisia leaf extract @ 2%. Other botanicals viz., Neem oil@ 3%, castor oil@ 2%, Artemisia leaf extract @ 3%,

NSKE @ 2%, NSKE @5%, Azadirachtin @ 0.2% and 0.3% showed 31.8%, 25.0%, 25.0%, 30.0%, 27.3%, 25.0% and 30.0% maximum mortality of coccinellids respectively. At 15th days after treatment, two botanical, Artemisia leaf extract @ 3% and Azadirachtin @0.3% gave 50.0% highest mortality of coccinellids while as least (25.0%) mortality of Coccinellids was recorded against Neem oil @ 2% as compared to treated check (Dimethoate 30EC @ 1.0ml/liter of water) the mortality was recorded as 55.5% of Coccinellids 65.0% of syrphid fly and 58.3% of Chrysoperla larvae at 1st days after treatment. Highest percent mean parasitization (8.1 and 8.5%) were recorded against Artemisia leaf extract @ 2% and 3% followed by treated check and least 3.4% was observed against Neem oil @ 0.3% concentration.

Seventh days of treatment, mortality of predatory natural enemies was increase slightly and all botanical pesticides showed similar trends as found at 1st day after treatment. At 15th day after treatment, the trend was also similar to 7th days after treatment and highest mortality of coccinellids (50.0%), syrphid fly larvae (56.2%) and Chrysoperla larvae (50.0%) against Azadirachtin@ 0.3%, Castor oil @ 3% and NSKE @5%, respectively.

The cumulative highest mean mortality of Coccinellids was recorded highest (33.33%) against Azadirachtin @ 0.3% followed by (33.23%) against castor oil @ 0.3% and Neem oil @ 3%which were statistically similar to each other and the least (18.03%)cumulative mean mortality was recorded against Neem oil @ 2% . The highest cumulative mean mortality of syrphid fly and Chrysoperla larvae was recorded 31.80% and 37.50% against Azadirachtin @ 0.3% and Artemisia leaf extract @ 3% respectively while as least mortality of syrphid fly larvae (16.00%) and Chrysoperla larvae (28.30%) were recorded against Neem oil @ 2% and castor oil @ 2%, respectively. The total mean mortality of natural enemies (35.26%) against Artemisia leaf extract @ 3% followed by Azadirachtin @ 0.3% and was recorded as 32.11%. The least mortality of natural enemies was recorded as 22.92% against Artemisia leaf extract @ 3% as compared to treated check which was recorded as 70.00%. Information was recorded against effect of botanicals pesticides on natural enemies' population of cabbage aphids was scanty, some workers such as Khan [14, 19] reported some pesticides and oils for the biosafety of natural enemies of mealy cabbage aphids of Kashmir. Khan, 2020 [34] worked and similar results against green apple aphids in same condition.

Table 1: Bio-efficacy of Botanical pesticides against cabbage aphid (*Brevicoryne brassicae*) in Cabbage field of Kashmir

Treatment	Conc.	Pre-treatment count			Total (Mean)	Post treatment count (Mean Population of *Brevicoryne brassicae* DAT)									Cumulative Mean			Total (Mean% reduction)
						1			7			15						
		N	A	Ap		N	A	Ap	N	A	Ap	N	A	Ap	N	A	Ap	
Neem oil	2%	38.6	19.0	17.2	74.8	19.4 (49.74)	10.2 (46.3)	9.6 (44.18)	16.2 (58.03)	9.6 (49.47)	8.6 (50.0)	11.4 (70.46)	9.2 (51.57)	6.8 (60.46)	15.6 (59.43)	8.93 (49.11)	8.33 (51.54)	32.92 (53.36)
	3%	40.2	17.8	15.6	73.6	19.6 (51.24)	9.4 (47.19)	7.2 (53.84)	16.0 (60.19)	8.4 (52.80)	6.4 (58.97)	10.4 (74.12)	7.8 (56.17)	5.6 (64.10)	15.33 (61.18)	8.53 (52.05)	6.4 (58.97)	30.26 (57.40)
Castor oil	2%	41.8	19.2	16.8	77.8	24.2 (42.10)	12.6 (34.37)	10.4 (38.09)	20.6 (50.71)	10.2 (46.87)	8.6 (48.80)	17.2 (58.85)	9.8 (48.95)	6.4 (61.90)	20.66 (50.57)	10.86 (43.39)	8.46 (49.59)	39.98 (47.85)
	3%	42.2	19.8	20.2	82.2	23.4 (44.54)	11.2 (43.43)	11.2 (44.55)	19.2 (54.50)	10.0 (49.49)	9.4 (53.46)	16.8 (60.18)	9.4 (52.52)	7.2 (64.35)	19.80 (53.08)	10.2 (48.48)	9.26 (54.12)	39.26 (51.89)
Artemisia leaf extract	2%	39.0	20.6	19.4	79.0	24.2 (37.94)	13.0 (36.89)	11.4 (41.23)	20.2 (48.2)	11.6 (43.68)	9.2 (52.57)	18.3 (53.07)	10.4 (49.51)	7.6 (60.82)	20.9 (46.40)	11.6 (43.36)	9.40 (51.54)	41.90 (47.10)
	3%	38.2	19.4	20.0	77.6	23.6 (38.21)	11.2 (42.70)	10.8 (46.00)	18.8 (50.78)	9.8 (49.48)	8.4 (58.00)	16.4 (57.06)	8.4 (56.70)	7.4 (63.00)	19.6 (48.68)	9.8 (49.62)	8.86 (55.66)	12.75 (51.32)
NSKE	4%	40.4	16.8	18.4	75.6	21.0 (48.01)	9.8 (41.66)	10.6 (42.39)	18.6 (53.96)	9.2 (45.23)	7.8 (57.60)	16.2 (59.90)	6.8 (59.52)	6.6 (64.13)	18.6 (53.95)	8.6 (48.80)	8.33 (54.70)	35.53 (52.48)
	5%	42.6	18.8	17.2	78.6	21.4 (49.76)	10.4 (44.68)	8.8 (48.83)	18.2 (57.20)	9.0 (52.12)	7.2 (58.13)	16.2 (61.97)	7.2 (61.70)	6.0 (65.11)	18.6 (56.33)	8.86 (52.83)	7.33 (57.35)	34.79 (55.50)
Azadirectin	0.2%	39.8	17.6	18.2	75.6	18.6 (53.26)	8.8 (50.0)	6.2 (65.93)	16.4 (58.79)	7.4 (57.95)	5.6 (69.23)	11.4 (71.35)	5.8 (67.04)	4.8 (73.62)	15.46 (61.13)	7.33 (58.33)	5.53 (69.59)	28.32 (63.01)
	0.3%	43.2	20.4	18.6	82.2	19.4 (55.09)	9.6 (52.74)	5.8 (68.81)	15.8 (63.42)	8.2 (59.80)	4.6 (75.26)	11.0 (74.53)	6.2 (69.60)	3.8 (79.56)	15.4 (64.34)	8.0 (60.78)	4.73 (74.54)	28.13 (66.55)
Treated check (Dimethoate 30EC)	1ml/L	42.4	17.8	19.2	79.2	11.4 (73.11)	6.4 (64.40)	5.6 (70.83)	10.6 (75.0)	5.2 (70.78)	4.2 (78.12)	9.8 (76.88)	4.8 (73.03)	3.4 (82.29)	8.2 (80.66)	3.2 (82.02)	4.40 (77.08)	15.8 (79.92)
Control	(Water)	43.6	19.6	18.0	81.2	45.0 (-3.21)	21.2 (-8.16)	18.4 (-2.22)	47.2 (-7.79)	21.6 (-10.6)	19.2 (-6.66)	49.6 (-13.07)	22.0 (-17.34)	20.4 (-12.22)	47.26 (-8.40)	21.6 (-10.6)	19.33 (-7.38)	88.19 (-8.61)
CD(P=0.05)		2.19	1.98	2.03	-	1.69	2.04	1.59	2.74	1.85	1.67	2.14	1.45	1.88	-	-	-	-

Mean of 5 replications, Figure in parenthesis indicates mean% reduction of aphid population, N= nymph, Al= Alate, Ap= Apterus
DAT= days after treatment, Population of *Brevicoryne brassicae* count on the basis of per leaf

Table 2: Bio-safety of Botanical pesticides against natural enemies of cabbage aphid (*Brevicoryne brassicae*) in cabbage field of Kashmir

Treatment	Conc.	*Pre-treatment count			Mean	P (%)	*Post treatment count (Mean population of Natural Enemies DAT)												Cumulative mean			Total (Mean% reduction)	Mean (P%)
							1				7				15								
		C.	S.	Ch.			C.	S.	Ch.	P (%)	C.	S.	Ch.	P (%)	C.	S.	Ch.	P (%)	C.	S.	Ch.		
Neem oil	2%	2.4	1.5	0.8	4.7	10.4	2.1 (12.5)	1.4 (6.6)	0.7 (12.5)	8.2	2.0 (16.6)	1.3 (13.3)	0.5 (37.5)	7.9	1.8 (25.0)	1.1 (26.6)	0.5 (37.5)	6.7	1.96 (18.03)	1.26 (16.0)	0.56 (30.0)	3.78 (19.57)	7.6
	3%	2.2	1.8	1.0	5.0	8.4	1.7 (22.7)	1.6 (11.1)	0.8 (20.0)	6.4	1.5 (31.8)	1.4 (22.2)	0.7 (30.0)	6.0	1.2 (45.4)	1.3 (27.7)	0.6 (40.0)	5.4	1.46 (33.3)	1.33 (26.1)	0.7 (30.0)	3.49 (30.20)	5.9
Castor oil	2%	2.4	1.6	1.2	5.2	11.2	2.0 (16.6)	1.4 (12.5)	1.0 (16.6)	9.7	1.8 (25.0)	1.2 (25.0)	0.9 (25.0)	8.2	1.5 (37.5)	0.7 (56.2)	0.7 (41.6)	7.3	1.76 (26.36)	1.10 (31.75)	0.86 (28.3)	3.72 (29.60)	8.4
	3%	1.8	1.2	1.0	4.0	9.2	1.4 (22.0)	1.0 (16.6)	0.8 (20.0)	7.1	1.2 (33.3)	0.9 (25.0)	0.7 (30.0)	6.7	1.0 (44.4)	0.6 (50.0)	0.6 (40.0)	6.4	1.20 (33.23)	0.83 (30.8)	0.70 (30.0)	2.73 (31.75)	6.7
Artemisia leaf extract	2%	2.2	1.8	0.8	4.8	11.8	2.0 (9.0)	1.6 (11.1)	0.6 (25.0)	10.0	1.8 (18.0)	1.4 (22.2)	0.5 (37.5)	8.9	1.5 (31.8)	1.2 (33.3)	0.5 (37.5)	7.4	1.76 (19.6)	1.40 (22.2)	0.54 (32.5)	3.70 (22.92)	8.8
	3%	1.6	1.2	0.8	3.8	10.0	1.4 (12.5)	1.0 (16.6)	0.6 (25.0)	8.7	1.2 (25.0)	0.8 (33.3)	0.5 (37.5)	7.6	0.8 (50.0)	0.7 (41.6)	0.4 (50.0)	7.0	1.13 (29.16)	0.83 (30.1)	0.50 (37.5)	2.46 (35.26)	7.7
NSKE	2%	2.2	1.6	1.2	5.0	7.8	1.8 (18.8)	1.4 (12.5)	1.0 (16.6)	8.9	1.6 (27.3)	1.2 (25.0)	0.8 (33.0)	8.7	1.2 (45.5)	1.1 (31.2)	0.7 (42.0)	7.9	1.53 (24.93)	1.23 (23.1)	0.83 (31.0)	3.59 (28.6)	6.8
	5%	2.0	1.0	1.0	4.0	9.2	1.8 (18.18)	0.9 (10.0)	0.8 (20.0)	7.4	1.4 (30.0)	0.7 (30.)	0.7 (30.0)	6.8	1.2 (40.0)	0.6 (40.0)	0.5 (50.0)	6.3	1.46 (26.66)	0.73 (27.0)	0.63 (37.0)	2.82 (29.50)	8.5
`Azadirectin	0.2%	2.4	2.0	1.4	5.8	7.2	2.0 (16.6)	1.8 (10.0)	1.2 (14.3)	6.8	1.8 (25.0)	1.6 (20.0)	1.0 (28.6)	6.1	1.4 (41.6)	1.5 (25.0)	0.8 (42.8)	5.2	1.73 (27.73)	1.63 (19.0)	1.00 (28.5)	4.36 (24.82)	6.0
	0.3%	2.0	2.2	1.0	5.2	8.4	1.6 (20.0)	1.8 (27.3)	0.8 (20.0)	6.2	1.4 (30.0)	1.5 (31.8)	0.7 (30.0)	5.4	1.0 (50.0)	1.2 (45.5)	0.6 (40.0)	4.8	1.33 (33.33)	1.5 (31.8)	0.7 (30.0)	3.53 (32.11)	5.4
Treated check (Dimethoate 30EC)	1ml/L	1.8	2.0	1.2	5.0	9.2	0.8 (55.5)	0.7 (65.0)	0.5 (58.3)	8.4	0.6 (66.6)	0.5 (75.0)	0.4 (66.6)	7.4	0.4 (77.3)	0.3 (85.0)	0.3 (75.0)	6.7	0.6 (66.46)	0.5 (75.0)	0.4 (66.6)	1.50 (70.00)	7.5
Control (Water)	Use water only	2.6	2.4	1.0	6.0	10.2	2.5 (3.8)	2.3 (4.1)	1.0 (0.0)	11.2	2.4 (7.6)	2.3 (4.1)	0.9 (10.0)	12.4	2.4 (7.6)	2.2 (8.3)	1.1 (-10.0)	13.5	2.43 (6.33)	2.21 (5.83)	1.0 (0.0)	5.69 (5.16)	12.4
CD(P=0.05)		0.13	0.18	0.12	-	2.4	0.4	0.3	0.09	2.6	0.19	0.32	0.40	2.5	0.61	0.37	0.08	1.47	-	-	-	-	-

Mean of 5 replications, Figure in parenthesis indicates mean% reduction of natural enemies

C= Coccinellids, S= Syrphid fly larva, Ch. = Chrysoperla, P= parasitized aphid (mummified), DAT= days after treatment, *Natural enemies count on the basis of 10 leaves.

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